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Changing culture : educating the next computer scientists

ADSHEAD, Deborah <http://orcid.org/0000-0002-1331-1794>, BOISVERT, Charles <http://orcid.org/0000-0002-3069-5726>, LOVE, David and SPENCER, Phil

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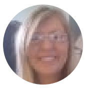

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Changing Culture: Educating the Next Computer Scientists

Deborah Adshead
Department of Computing
Sheffield Hallam University
Sheffield, United Kingdom
d.adshead@shu.ac.uk

Charles Boisvert
Department of Computing
Sheffield Hallam University
Sheffield, United Kingdom
c.boisvert@shu.ac.uk

David Love
Department of Computing
Sheffield Hallam University
Sheffield, United Kingdom
d.love@shu.ac.uk

Phil Spencer
Department of Education
Sheffield Hallam University
Sheffield, United Kingdom
p.spencer@shu.ac.uk

ABSTRACT

Since 2012 the United Kingdom has initiated a radical change of the culture of computing teaching: the subject matter, the reliance on university specialists, even the subject name has changed. Sheffield Hallam University's response has been to involve academic staff from both the Department of Education and the Department of Computing, eventually forming the Centre for Computing Education.

The aim of our integrated approach is to help support the culture change in progress. Through the Centre's work, a new generation of young teachers and trainees are being supported to embrace the cultural change. The growing use of tools and resources we provide, the visits, events, and teacher support network is strengthening the curricular shift in many schools.

However, the challenge remains to reach those schools who, so far, struggle to engage with the depth of change in the curriculum. Whilst still young, we believe that our integrated approach can continue to make a strong contribution to the culture change of teaching computer science at K-12 level in the United Kingdom.

Categories and Subject Descriptors

Social and Professional topics [**Professional topics**]: Computing Education—*K-12 Education*; Social and Professional topics [**Professional topics**]: Computational Thinking

General Terms

K-12 Computer Science Education

Keywords

Computing at Schools, Computer Science Education, Secondary Education, K-12 Teacher Training

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1. INTRODUCTION

In 2012 the United Kingdom (UK) Government began a response to industry calls to radically change the teaching of 'computing' in schools in England and Wales [1, 7]. This ambitious programme aims to change not just the skills of teachers involved in computing education [9], but also to radically change the teaching *culture*. Specialist teaching in 'Information and Communications Technology' (ICT) would no longer be the reserve of specialist schools, but would be something brought into the main-stream education of schools within England and Wales [10, 11]. Through the 'Network of Teaching Excellence in Computer Science', new links would be forged between Universities and schools — and even the subject name would be changed to 'Computer Science' to reflect the enhanced subject status [4, 22].

With a long history of primary and secondary teacher training, Sheffield Hallam University has been involved in the 'Computing at Schools' programme since the initiative was announced. An almost unique feature of the response from Sheffield Hallam University, however, has been in the involvement of academic staff from both the Departments of Education and the Department of Computing.

The engagement by staff from the Department of Computing has also been focused on in-school delivery of special lessons and knowledge transfer rather than simply supporting the changes to the new teacher training requirements.

This has given academic staff in the Department of Computing a track-side view of the changes in computing education both in school, and reflected in student applications to the Department of Computing. Changes inside (and outside) schools have certainly occurred since 2011.

But have these changes been enough to radically alter the culture of computing education within England and Wales?

2. CONTEXT AND WORDING

To make it very clear for a global audience, we will refer to different levels of education, not by some national education standard, but by age. By "K-12" we mean all pre-university education from kindergarten to (typically at 18) 12th grade; within this, primary education is up to 11 years old, and secondary the older half to 18. Post 18, higher education is to obtain a first degree (undergraduate), or a higher degree (postgraduate).

In the UK most teachers undertake a one-year qualifying postgraduate diploma, the *Post-Graduate Certificate in Education* (PGCE): which we will refer to, for simplicity, as "teacher training" or "initial teacher training". Education is also offered to qualified teaching staff, to improve their skills or support them in a changing environment, through formal *Continuous Professional Development* (CPD).

This vocabulary established, we can describe the recent history of IT Education in the UK. The teaching of computing in schools has a long and distinguished history in the UK, including for example the creation of the BBC microcomputer, made specifically for school education in 1981 [8, 3]. But as in many other countries, the curriculum shifted to teaching the day-to-day, office applications of computing under the name of *Information and Communications Technology* (ICT); by the mid-2000s the disastrous consequences of poor computing K-12 education were clear, with a crisis in undergraduate recruitment in the field and a mismatch between teaching and student expectations. Computing academics and professionals lobbied for change and in 2011, the UK Department for Education responded with a challenge, and their demands were made into a reality in a matter of months, by introducing code in the curriculum of secondary schools. To signify the change, 'ICT' was renamed 'computing'.

The recent changes to the national curriculum to introduce increasing amounts of computing across the key stages have created considerable amounts of both concern and positive anticipation. Concern, due to the lack of training and support which the teaching profession are receiving to allow them to deliver this new curriculum and positive anticipation, because for many of us, teaching some 'real' computing is something that we have been wanting to do for some time. As a subject ICT has, for some time been a poisoned brand for a number of reasons: not least that it was a 'simple' subject that anyone can teach. The speech by the UK Secretary of State for Education, Michael Gove, in January 2012 demanding change [13] was seen as the final nail in the coffin for ICT.

3. AN INTEGRATED ANSWER FROM SHU

3.1 An Enthusiastic Response

But the very short interval between the announcement of the curriculum changes and the delivery in school created a difficult task for schools. This difficulty was greatly exacerbated by the historic paucity of teachers trained in the tools and methods of computer science; and of the general lack of staff with a basic knowledge of computer science [7, Chapter 7]. Nonetheless, *ad hoc* links had developed between individual IT teachers or secondary schools and academics within the Departments of Education or Computing over previous years. Instead of formalising a response to schools from only one Department, staff within the two Departments worked together to deliver a combined 'Computing at Schools' programme as soon as the government initiative was announced. A pilot scheme was developed in May 2012 to test the viability of our proposal. The joint-venture was very productive and eventually was named, to help identify our work for enquiring schools, the *Centre for Computing Education.* In this paper, for simplicity, we will attribute joint education work from the two departments to that Centre, even though much was initiated before the Centre for Computing Education was officially formed.

We believe that our joint response to these school needs at Sheffield Hallam University holds lessons for any higher education academic wishing to get involved in K-12 Computing education. The teaching context of computer science within a University is very different from that of secondary schools, and academics within the Department of Computing had to pick up skills very familiar to those in the Department of Education. Simultaneously, academics from the Department of Computing could bring a broad subject expertise to colleagues in the Department of Education: an expertise which has been a necessary support in the rapid re-development of the teacher training programme.

As the possibility of supporting schools transitioning from ICT to computing became clear, the response of colleagues in the Department of Computing was enthusiastic. Staff offered their time and resources in many areas, proposing ways to engage the children using mobile technologies, robotics, unplugged activities, original uses of Scratch and many more, and to host classes in the university as well as deliver sessions in schools.

A third characteristic of our involvement in schools comes from the students. Student engagement in K-12 education is not new: and indeed the Department for Education has long been engaged in mentoring student activities with schools [2]. In addition the University also has structures in place to employ students on a casual basis, for example as Student Ambassadors welcoming and giving tours to young visitors or newcomers, and a formal Hallam Award scheme to support students' engagement outside their studies.

Initial meetings led to a proposition that would link all of the above: the relationship with schools; the involvement of Education and Computing staff; the support of student volunteers; and the double offer of travelling to schools, and welcoming pupils on the University site. To allow the involvement of students, the respective roles of school staff, university lecturers and students were clearly defined: school staff would always remain present to manage their pupils and ensure the respect of school child protection obligations; university staff prepared resources and tools — hardware, software, teaching materials — demonstrated them to volunteer students in advance of the sessions to help them prepare, and led the sessions with pupils. Students, paid per-hour for their involvement, also assisted in supporting pupils during lessons. The aims were to ensure that when working with technology that is unusual in schools, any difficulties with hardware and software, or any complexity, such as programming syntax, that would be a barrier to the purpose of the session, could be ironed out quickly with help, allowing the pupils to focus on higher learning goals; but also to provide much-needed role models for the school children.

Finally, the Education staff joined in the visits and complemented them with offers of regional meetings to support teachers in post, continuous professional development to improve their level of qualification, placement for new trainee teachers, and a new qualification to train teachers in computing. In all, including the pilot sessions in May 2012, we have delivered: 8 sessions to 5 different schools in the summer 2012; 18 sessions in the academic year 2012–13 to the same schools plus a further 7 schools; and 20 in 2013–14, adding 8 more schools to our portfolio. The programme is ongoing this academic year.

Therefore the engagement by staff on all sides went much

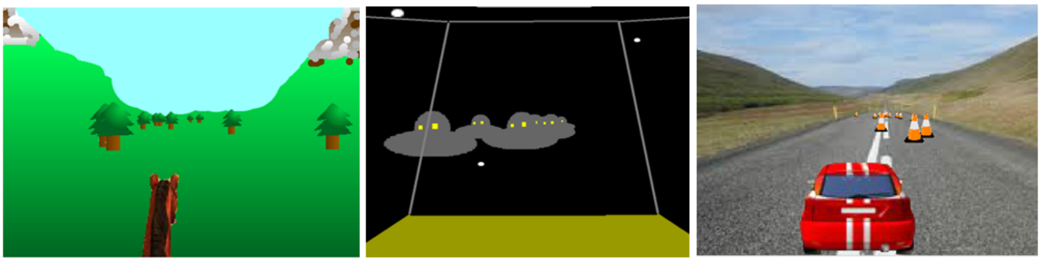

Figure 1: multiple themes to support pupils' creation

further than simply delivering a specific action within their role: we all became involved in support of change, working to understand the new teaching demands from teachers, supporting their training requirements, as well as the more common, in-school delivery of special lessons and knowledge transfer.

3.2 Our Offer to Teachers: Some Examples

Some examples of the events offered will illustrate the diversity and multiple aim of our offer to schools. These examples are taken among the more frequent and popular events, but an exhaustive list would be beyond the scope of this paper.

3.2.1 Scratch 3D

Scratch is well known in schools and it may not be apparent why school pupils and teachers need more intervention to learn the language. But our visits show that its use, although common, remains limited to shallow, repetitive uses of the software. The aim of our visits is to help pupils and teachers alike to break into more creative and diverse uses of Scratch which link to computational thinking.

To spur the interest of pupils we created a set of resources that simulate 3D in scratch. The material provided includes some ready code, but also ready art (Figure 1), because pupils often spend more time drawing than programming, missing out on learning to control their systems' behaviour. The students' involvement is precisely to help ensure that pupils do not get stuck in a rut [21, 16, 18], and exploit the ideas further with original uses.

The pupils typically start by closely following the guidance they receive. From it they are able to make diverse animations and games. A final activity is for those who wish to present their ideas to their class.

The session is more difficult to manage than using robots — it has to counter the expectation that Scratch is extremely limiting, and it does so by offering a project that challenges the pupils, but also the volunteer students, who need to understand the 3D simulation in greater depth.

3.2.2 Racing Robots

The most popular lessons, repeated in many schools since 2011, has been programming small robots. The robots used (Pololu 3PIs) were chosen for their sturdiness and simplicity. As well as the robots, we make available laptops ready configured with the development environment.

Students are able to iron out any problems that result from handling the environment, being used to this already, making the experience much more enjoyable for the pupils as this minimises the frustration of having exciting tools but too many barriers to use them.

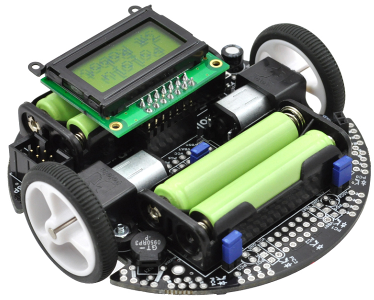

Figure 2: Pololu 3PI Robot (Source: Pololu Corporation [6])

Figure 3: Robots at the Ready

Two typical problems that pupils work out are to ensure the robot goes in a roughly straight line (a genuine problem in a real world of motors, gearing, dust and voltage drops, as opposed to tracing lines on digital images!), and can carry a load (a marble, carefully balanced on the two batteries) (shown in Figure 2) without dropping it as the robot speeds up, slows down, and turns around. This culminates into a race between the robots, to find which can carry the load to a line and back without dropping it (Figure 3).

The session is very successful with pupils and motivates them to shift from visual, drag-and-drop coding tools like Scratch, to coding in C. Additional support is required to ensure that the children's focus is on debugging, not on correcting syntax errors. Nonetheless, several school teachers have since chosen to use the same robots in their schools, in new computing lessons or through in-school clubs.

3.2.3 FIRST Lego League

The 'status' of in-school clubs, however, illustrates one of the key weaknesses of the UK 'Computing at School' programme. In 2006 the UK Government created the *After-School Science and Engineering Clubs* (ASSEC's) programme, designed to inspire pupils aged 11–14 to learn about science and engineering [24]. The activity of these clubs has been co-ordinated and supported by the *Science, Technology, Engineering and Mathematics Network* (STEMNet), a UK charity partly supported by Government funding.

In schools where ASSEC clubs are well-established, the 'Computing at School' activities have largely been folded into the existing clubs. Where no previous ASSEC club exists, a new in-school club is usually created (and sometimes then linked to the ASSEC programme). Confusion over programme delivery is hardly novel, but it does lead to challenges in supporting the broader 'Computing at School' objectives.

The teaching background of staff supporting ASSEC clubs is largely design technology [24, pp. 19–20]: traditionally in the UK a very different teaching discipline to computing. So while many STEM ambassadors (external volunteers co-ordinated, trained and monitored by STEMNet) come from a broad range of engineering and computing disciplines, the in-school support for ASSEC clubs has historically been much narrower. Therefore while robotics and computing activities may be popular with pupils, schools must often rely on teachers voluntarily picking up skills in a new field.

Using peer-support through the *Continuing Professional Development* (CPD) programmes at Sheffield Hallam is one approach to ensuring the continued success of 'computing' clubs in school). Another is to link into national (and international) competitions based around engineering and computing to provide both a framework for supporting the teachers — and additional self-learning resources for the pupils.

At Sheffield Hallam we have been involved in the FIRST Lego League since 2013, acting as regional host in the UK. Originating in the United States, but now well-established internationally, the FIRST Lego League is an international competition involving an annual 'challenge': part of which is solved by Lego robots solving a fixed set of problems, and part of which involves presenting a broader engineering solution to the challenge topic [20, 19]. The running of the national League in the UK is co-ordinated by the *Institution for Engineering and Technology* (IET): the body overseeing the professional regulation of electrical and computing engineers in the UK [12].

Since schools work on the first round of the FIRST Lego League over a period of roughly three months, this activity offers the potential for substantial links between schools and staff inside the University. At present, however, much of this potential has yet to be realised. Teams established before Sheffield Hallam took over the Sheffield regional event only rarely ask for support from the University. Teams that do ask for support however, would prefer regular (usually weekly) engagement along the lines of the ASSEC clubs. But while STEMNet offers comprehensive support and training of STEM ambassadors (including managing the extensive documentation required for volunteers to work in UK schools), finding a similar support structure for the 'Computers at School' programme has been difficult.

Practically, this means that all students who want to work with schools on a regular basis for the FIRST Lego League have to become STEM ambassadors first. While this is not a tremendous burden (and indeed offers the students many other opportunities), it does lead to questions over the long-term viability of 'Computers at School' clubs. Especially when a 'competing' support structure in overlapping disciplines that already exist.

3.3 Our Offer to Students

As well as supporting schools with sessions on school grounds and here on site at the University, it was also seen as important to involve students currently studying for computing related degrees at the University. We have already mentioned the importance of providing a larger pool of support for delivering sessions, but involving the students is also invaluable for them, and we work to maximise that value.

Students with some programming experience are recruited at intervals throughout the year to act as paid mentors. Some also volunteer unpaid for the Hallam award — a university award given for voluntary work. Both then attend Masterclasses in the subject material prior to taking part in any teaching activities, and sessions are divided as evenly as possible amongst the trained students based on their availability and their interests.

Since 2012, we have recruited over 70 students to participate in delivery of the sessions. Many of those involved are undergraduate, but some postgraduate students at Master or (more rarely) PhD level are also involved. The direct involvement of students in delivering the sessions has many benefits: it provides students with valuable work experience to add to their CVs; it helps reinforce the students' skills and subject knowledge as they practice them in a different context and at a simpler level; it fosters a peer learning environment with students helping each other, and meeting across the usual barrier of level of study and detailed specialisms.

Some students are considering the idea of becoming computing teachers in schools themselves, and for those, the volunteering or hourly-paid opportunities are a way to test the waters of a school teaching environment before committing themselves to teacher training.

3.4 Providing Teacher Education

The main problem for school Computing, is the lack of specialist teachers who are able to deliver the topic with confidence. As we have said, most teachers who were teaching ICT are not Computing specialists [7, *op. cit.*], so finding ones with computing qualifications is a considerably difficult thing to do.

From the outset of the involvement in the Computing at Schools initiative, staff at Sheffield Hallam University were committed to developing a support structure to the schools that would benefit not only the school children who would be attending taught sessions but would also help to cultivate a culture of professional development for the teachers. This takes two main forms: continuous development for teachers already in post, who need to retrain into computing from ICT — and sometimes from unrelated specialisms altogether [7, Chapter 7, *op. cit.*]; and a one-year teacher training qualification, in the new Computing discipline, for incoming teachers.

3.5 CPD of Established Teachers

Whilst it is not a requirement to be involved in the initiative, the teachers of the participating schools are offered several opportunities to support their development from ICT to Computing specialists. This activity, is limited by the amount of time staff are given to attend such sessions as well as the funding given to schools to allow teachers to undergo training; but the Centre for Computing Education aims to provide a diverse offer to reach the broadest possible audience.

At the simplest level, all the resources — handouts, software tools, information about the practice — resulting from the visits are made available to teachers, open to re-use and adaptation for later classes. Between other results, this open culture has facilitated the adoption of robots by two of the schools, and the development of local computing clubs to use them.

Further, building on its positive working relationships with a large number of secondary schools, the University's Department of Education acts to support via a range of CPD events. It leads a regional 'hub' for the 'Computing at School' programme, periodically hosting the 'Computing at School' meetings and different outreach workshops. These enable us to support schools with new ideas, resources and activities.

Finally, teachers are encouraged to attend weekend and evening workshops delivered by the joint Centre for Education in Computing. Through these, teachers who are not qualified in the subject can develop their knowledge and obtain a qualification validated by the *British Computer Society* (BCS[1]); but those who are already knowledgeable in Computing can also become 'master teachers', and support training of new teachers, also with the approval of the BCS.

3.6 Training New Teachers

New teachers are, of course, being trained via the PGCE Computing route. This teacher training qualification includes placements in secondary schools; and students are placed in schools that may not have specialist staff, deliberately to facilitate the exchange of technical knowledge, as well as support the development of teaching skills.

However, while Government funding has increased the number of teacher training positions in Computer Science, intervening changes in the national teacher training programme has led to an overall decrease in the number of student teachers [25]. Thus there is a concern that we will not be able to produce sufficient new teachers to meet the requirements of schools in the area. This being said, we do have a cohort of 15 teachers who are currently studying a PgCert in Education with a focus on computing. This has been a positive experience for all as we have not only looked into pedagogical and theoretical issues, but it has allowed the formation of a group of schools who are offering further support to other schools in the area.

The strong development of teacher training is very much a result of the concerted action of the Centre for Computing Education over the past three years. Take the case of current teacher trainee, Emily (not her real name). As an undergraduate student at the university, Emily was interested in the lack of role models for girls who, like her, would be interested in studying computing; she was also on the lookout for paid work while studying. This double interest found a natural home when, in her final year, she joined the pool of students mentors.

Her commitment to education only strengthened as she visited schools and welcomed children in the University helping with robot races, 3D scratch, mobile development lessons for secondary schools. Through these visits she also met with experienced teachers and with the teacher training staff, and this academic year she is completing her own teacher training, having reinforced her professional interest thanks to the mentoring opportunities provided by the Centre.

4. SHIFTING THE CULTURE OF COMPUTING

As we explained in the introduction, the Centre for Computing Education was created in response to the UK government and industry hoping to not just improve the school curriculum, but to radically change the teaching of computing [2, 1]. This begs the question, are we contributing to such an ambitious change within England and Wales?

On the one hand, a radical transformation of the culture has taken place, which we have witnessed rather than initiated. In the short years before government changed the curriculum in 2012, industry was asking for such change. Academics were also concerned by a recruitment crisis[2]; the poor computing knowledge of their intake, and changing student demand clearly indicated the need for the change to a more science-based computing education. In the same period that saw changes to the school curriculum, student intake filled increasingly technical computer science courses, making them unexpectedly popular. We cannot attribute the new interest of students in computer science to the government initiative: their curriculum was not affected by it, as changes were proposed as they left school. The cultural change is therefore broader and more complete than any government-led initiative, and the agents of that change are multiple.

Yet the transformation is incomplete. In schools, the main concern is less with those schools who engage actively with the university, but with the many others who do not, for whatever reason. Many choose to ignore the need to support their staff through the change, still hoping that simple investment in recent hardware will magically solve the problem of teaching Computing, just as they did with 'technological toolery' in earlier ICT [17]. But tools by themselves are not enough [5]. Unless these staff can be reached and supported, there may be a clear two-tier situation in schools as far as the delivery of computing is concerned, with some schools under-performing or even, for those that are entitled to do so, such as academies, opting out of computing and thus ignoring a major branch of modern science.

The culture shift that industry, government and academics have all been working for is therefore in progress. We are, as Prof. Peyton-Jones describes in his campaigning work, in "*the ground war*" [15]: the struggle to train and disseminate the new ideas [14]. This would not happen without a multi-aimed approach to simultaneously recruit students, improve

[1]The British Computer Society is the professional body devoted to "*study and practice of Computing*" in the UK [23], acting as the main chartering body for computing and IT professionals outside the IET.

[2]For instance, the UK computer science student numbers in 2013–2014 are still only a two-thirds of the equivalent number in 2003–2004 [26, Table 3].

secondary education, lift the standard of school computing and counter the illusion that computing is IT.

Our multi-dimensional work finds a new challenge in the extension of coding to primary schools. Announced in 2013, coding in the primary school curriculum is an even greater challenge than for secondary school teachers, given that these schools do not employ subject specialists. Our response adapted the work started with secondary schools, through sessions that are shorter, more active, and carefully consider the level at which the children can work. In primary school sessions, we also gave students a greater role as they prepared and led unplugged activities, sessions on Scratch, and on using Scratch with Microsoft Kinect sensors. In this context, our integrated approach is helping support the culture change in progress. It provides, for example, the flexibility necessary to adapt to the needs of primary school teachers and start supporting them.

Through the work of our Centre for Computing Education, more teachers don't just buy, but use, the tools and resources provided — and develop Computing teaching materials. The visits, events, and Computing at School support network is strengthening the curricular shift in many schools. Finally, a generation of young teachers is being trained that is embracing that cultural change, and their placements are already influencing a new approach to the topic.

Nevertheless, despite our successes there is still a way to go. There still remains the challenge of reaching those schools who, by failing to engage with the changes in the curriculum through a shift in their culture, run the real risk of failing to support pupils who increasingly need the skills to fully comprehend, and to fit in to, an ever more technological world and workplace.

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